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Status of the Lake Whitefish Fishery in Lake Nipigon

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by

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Abstract

Various biological indicators were examined to assess the status of the lake whitefish (*Coregonus clupeaformis*) fishery in Lake Nipigon. Evaluation of yield, abundance, growth, maturity, age structure, year-class strength, mean age, mortality, and spawning opportunities indicate recruitment failure of lake whitefish. A negative interaction with rainbow smelt (*Osmerus mordax*) is the likely cause. Lake whitefish are presently harvested at maximum levels and yields are expected to decline. Reductions in allocation and harvest are recommended for the conservation of lake whitefish stocks. The maintenance of healthy populations of predator species is suggested as a means of limiting rainbow smelt abundance and protecting a balanced fish community.

Key Words

lake whitefish, rainbow smelt, fisheries assessment, stock status

Acknowledgements

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Introduction

The objective of this report is to review the status of the lake whitefish (*Coregonus clupeaformis*) fishery in Lake Nipigon and recommend a sustainable harvest level to managers.

Lake whitefish is the most valuable commercial species harvested from Lake Nipigon. Annual commercial catches of lake whitefish have averaged about 65 percent of the entire commercial harvest (all species) since the Lake Nipigon commercial fishery began in 1917. The total dockside value of commercially harvested Lake Nipigon whitefish exceeded $350,000 in 1994. Subsistence and recreational harvests of lake whitefish are also taken from the waters of Lake Nipigon.

Recent concerns about the potential impact of rainbow smelt (*Osmerus mordax*) and commercial harvest levels on Lake Nipigon whitefish (Ritchie 1989), and the need for timely assessment, analysis and reporting on the status of the fishery have been identified (OMNR 1991). To address these concerns, this report presents the most current information available regarding the status of Lake Nipigon whitefish and serves to update previous status reports (Borecky 1985; Savioja 1987; Ritchie 1989).

The status of the fishery is evaluated by examining various biological indicators to determine if the lake whitefish population is unduly stressed by exploitation. The indicators examined are yield, abundance, growth, maturity, age structure, year-class strength, mean age, mortality, and spawning opportunities. The interaction between rainbow smelt and lake whitefish is also examined. These biological indicators often provide evidence of exploitation stress and they are intended to be used in some combination as no single indicator is considered definitive (OMNR 1983). The status of the lake whitefish fishery is based on the accumulated evidence of stress revealed by the indicators examined.

Lake Description

Lake Nipigon is a large (4480 km^2), deep [137 metre (m) maximum depth], relatively unproductive, cold-water lake located in northwestern Ontario. The lake supports subsistence, recreational and commercial fisheries that harvest a wide variety of fish species including brook trout (*Salvelinus fontinalis*), lake trout (*Salvelinus namaycush*), northern pike (*Esox lucius*), walleye (*Stizostedion vitreum*), sauger (*Stizostedion canadense*), rainbow smelt and lake whitefish.

Data Collection

To monitor the status of the fishery, the Lake Nipigon Fisheries Assessment Unit (LNFAU) collects data from four primary information sources: index fishing, commercial fish reports, commercial catch sampling, and angler surveys. Lake whitefish index fishing programs are conducted annually at two sampling locations that are identified as WFN (northern site) and WFS (southern site) in this report.

Methods used in LNFAU sampling programs are described in detail by Borecky (1981, 1985), Borecky and Riordan (1982, 1984), Reid and Savioja (1986), Savioja (1987) and more recently by Ritchie (1989).

Indicators

Yield

Lake Nipigon has produced well over 20 million kilograms of lake whitefish since the commercial fishery began in 1917. Between 1917 and 1994, the commercial harvest has fluctuated about a mean of 258540 kg/yr (569,973 lbs.) which represents a long-term yield of 0.58 kg/ha/yr (Figure 1). The commercial harvest of lake whitefish has been relatively stable ($\bar{x}$=222465 kg/yr.; SD=22706 kg/yr) since quota management was initiated in 1982.

Subsistence harvest has not been estimated for Lake Nipigon as there is little information available.

The recreational harvest of lake whitefish is estimated at less than 100 kg/yr. This estimate is derived from angler surveys conducted at access points during 1993 and 1994 (OMNR unpublished data).

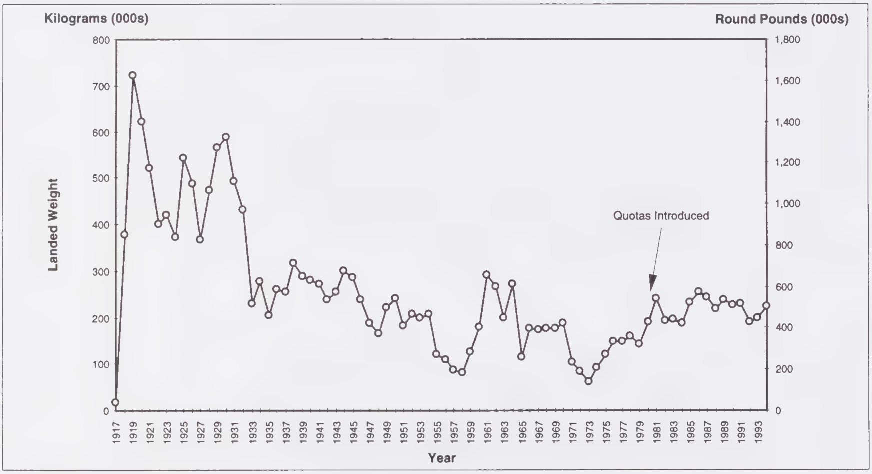


Figure 1: The reported annual commprcial catch of lake whitefish harvested from Lake Nipigon (1917–1994)

Potential yield is an estimate of the annual harvest that could be maintained without collapsing fish stocks; it is considered the upper limit of yield that a fishery will sustain under optimum conditions (OMNR 1983). However, it is considered unwise to exploit a fishery at full potential yield as it does not provide for any margin of safety (Larkin 1977; OMNR 1982).

Potential yield can be calculated using historical data (OMNR 1979, 1982) as long-term averaging of annual commercial catches provide estimates of maximum equilibrium yield in moderate to intense effort fisheries (Ryder *et al.* 1974). The estimated potential yield for Lake Nipigon whitefish is 258 540 kg/yr.

The relative yield index (RYI) is a ratio that provides an indication of exploitation levels by comparing potential yield to current yield values (OMNR 1983). It is calculated as follows:

$$\text{Relative Yield Index (RYI)} = \frac{\text{Current Yield}}{\text{Potential Yield}}$$

when
- RYI = 1 potential yield is achieved
- RYI < 1 potential yield is not achieved
- RYI > 1 potential yield is exceeded and overfishing is indicated

Application of the RYI to subsistence, recreational and commercial fisheries show that the Lake Nipigon whitefish fishery is being utilized at full potential yield (Table 1). The present commercial allocation of lake whitefish represents 99 percent of potential yield and the recreational harvest accounts for less than one percent.

Table 1: Yield estimates for Lake Nipigon whitefish.

	Current Yield[2,3]	Projected Use[4] (Year 2000)	Allocated Yield[5]
Subsistence Fishery	unknown	unknown	unknown
Recreational Fishery	75 kg/yr. (165 lbs.) RYI = 0.0003	100 kg/yr. (220 lbs.) RYI = 0.0004	unknown
Commercial Fishery	222 465 kg/yr. (490,442 lbs.) RYI = 0.86	256 500 kg/yr. (565,476 lbs.) RYI = 0.99	256 511 kg/yr. (565,500 lbs.) RYI = 0.99
Total Harvest	222 540 kg/yr. (490,608 lbs.) RYI = 0.86	256 600 kg/yr. (565,697 lbs.) RYI = 0.99	>256 511 kg/yr. (565,500 lbs.) RYI = 0.99

1 $\text{RYI} = \dfrac{\text{Yield Value (x)}}{\text{Potential Yield}}$

Potential yield = 258 540 kg. lake whitefish/yr for Lake Nipigon.

2 Current yield estimates for the recreational sport fishery are derived from angler surveys conducted in 1993 and 1994 (OMNR unpublished data).

3 Current yield for the commercial fishery is represented by the average annual reported harvest since quota was initiated (1982-1994).

4 Projected use values for the recreational fishery are from the Nipigon District Fisheries Management Plan (OMNR 1989).

5 The allocated yield value for the commercial fishery represents the total lake whitefish quota.

Abundance

Abundance is a biological statistic that describes the quantity of fish in a population. In response to stress, annual abundance often becomes more variable (Colby 1984). The use of abundance as an indicator of stock status involves comparing current abundance with some previous baseline condition and examining the range over which abundance varies between years (OMNR 1983). Variation in annual abundance can be expressed as the coefficient of variation (CV) which is calculated as follows:

$$\text{CV} = \frac{\text{Standard Deviation (SD)}}{\text{Sample Mean } (\bar{x})}$$

As a guideline for fisheries management, a CV in annual abundance approaching 0.40 is considered to be cause for concern as lake whitefish stocks designated as being over-exploited have a CV above 0.40 (OMNR 1983).

Lake whitefish abundance in Lake Nipigon is known only in relative terms, with annual commercial catch and index fishing catch-per-unit-effort (CUE) serving as indices of abundance. The historical record of commercial catches provides a baseline condition over which the annual variation can be measured (Figure 1). However, harvest levels are dependant on fishing effort as well as the quantity of fish. For the entire 1917-1994 period, lake whitefish harvest is highly variable (CV=0.54) with exceptionally large catches recorded in the early years of the fishery (1918-1931). More recently (1932-1994), annual catches have exhibited less variability (CV=0.33) and reflect a more stable fishery.

LNFAU Index fishing programs also provide a baseline condition over which variation in annual abundance can be measured (Table 2 and Figure 2). Coefficient of variation values for both sampling locations (CV=0.37) are below but approaching the guideline value of 0.40.

Table 2.:
Variation in Annual Abundance of Lake Whitefish (1983–1994).

Index Fishing	Mean CUE ($\bar{x}$)	Maximum CUE	Minimum CUE	Standard Deviation (SD)	Coefficient of Variation (CV)
WFN	1.30	2.05	0.49	0.48	0.37
WFS	0.92	1.71	0.55	0.34	0.37

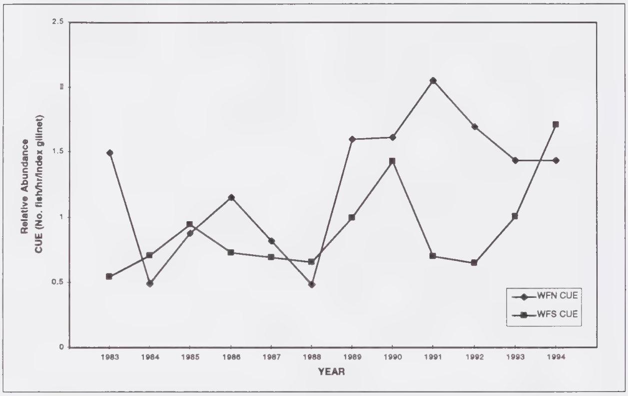


Figure 2:
Lake whitefish abundance—annual index CUE (1983–1994). Mean CUE values for lake whitefish captured in annual index fishing programs at two sampling locations (WFN and WFS).

1. CUE is expressed as the number of lake whitefish captured in one LNFAU standard index net per hour of fishing time.
2. Stocks designated as being over-exploited have a CV value >0.40 (OMNR 1983).

Growth

A healthy fish population is usually characterized by a steady growth rate while stressed populations often exhibit increasing or decreasing trends in growth (Colby 1984). A change in growth rate of lake whitefish stocks is often an indicator of change in exploitation levels (Healey 1975; Jensen 1981). However, a growth response will be limited by environmental conditions such as temperature and productivity (OMNR 1983).

Preferred and optimum growth temperatures for lake whitefish are reported to be within the ranges of 12° to 17°C (Schlesinger and Regier 1983) and 11° to 15°C (OMNR 1983). With surface water temperatures rarely exceeding 20°C in the summer months, Lake Nipigon is considered to provide favourable thermal habitat for maintaining of cold-water species such as lake whitefish (Savioja 1986).

Lake whitefish sampled in LNFAU index fishing programs exhibit a relatively stable growth rate (Figures 3 and 4) and growth is similar to the provincial standard for the species (Figure 5). An increasing or decreasing trend in growth is not evident.

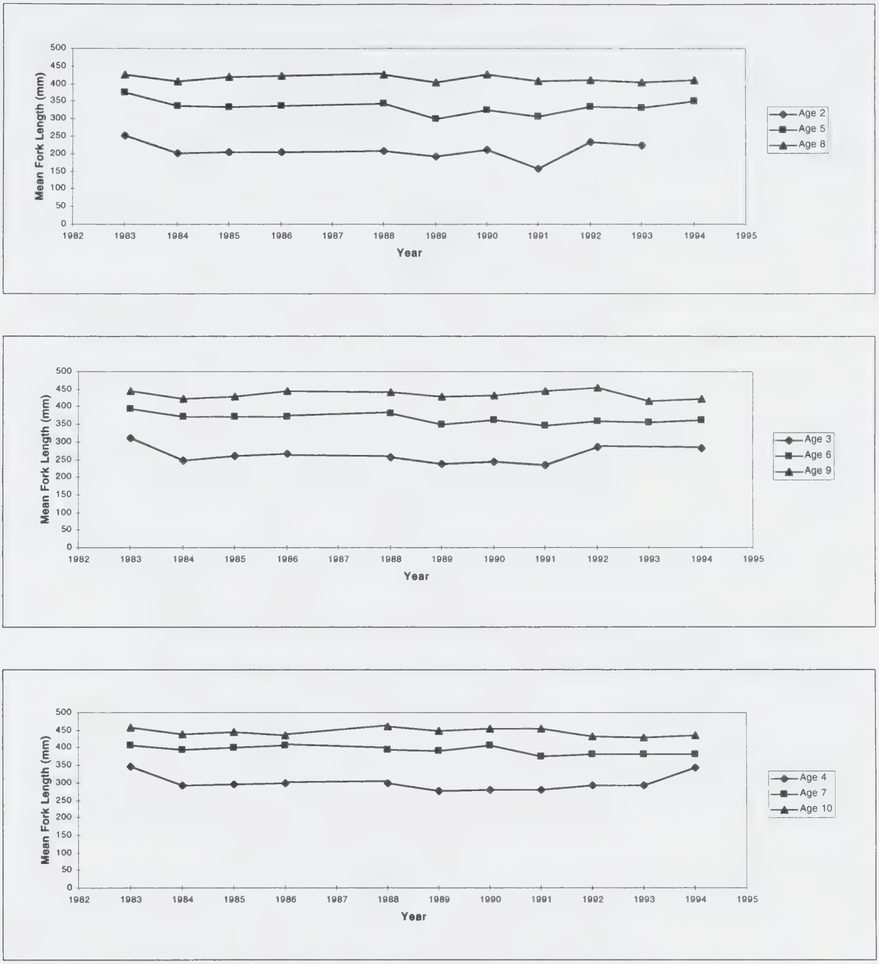


Figure 3:
Age specific growth trends—WFN index (1983–1994). Age specific mean fork length values for lake whitefish (ages 2–10) derived from annual WFN fishing programs.

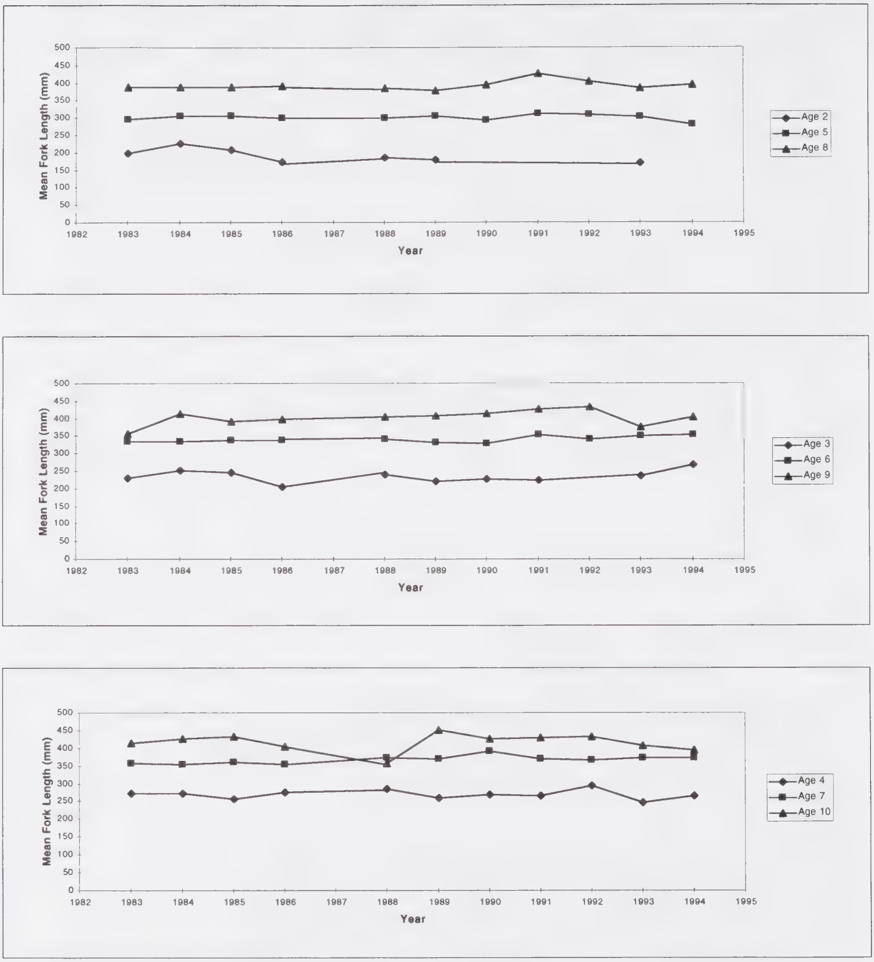


Figure 4:
Age specific growth trends—WFS index (1983–1994). Age specific mean fork length values for lake whitefish (ages 2–10) derived from annual WFS fishing programs.

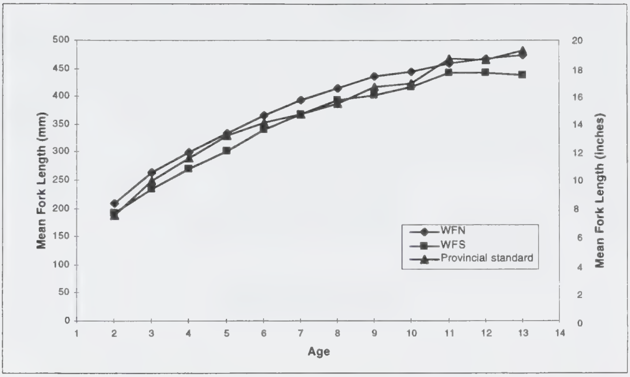


Figure 5:
Lake whitefish growth curves. Mean fork length (mm) at age (years) from index fishing programs (WFN and WFS) are plotted in comparison to the Provincial growth standard (OMNR 1983) for lake whitefish.

Maturity

Maturity refers to the ability to reproduce. Mean age at maturity is a statistic that describes the age at which the "average fish" spawns for the first time (OMNR 1983). Fish populations that are stressed by exploitation, changes in habitat and species introductions may exhibit changes in age at maturity (Colby 1984).

An increasing trend in age at maturity of lake whitefish is evident over the 1983 to 1994 sampling period (Figure 6).

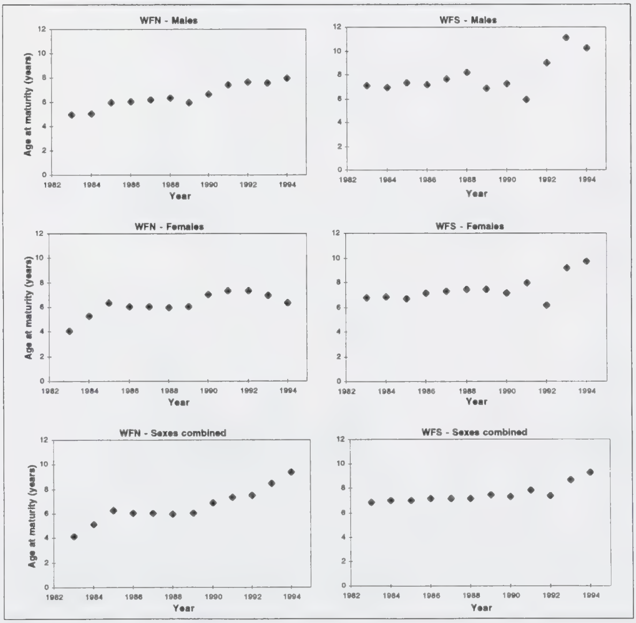


Figure 6:
Trends in mean age at maturity for Lake Nipigon whitefish—Index fishing (1983–1994). Mean age at maturity values for lake whitefish (calculated from WFN and WFS index catches) are plotted against the corresponding sample year.

Age Structure and Year-Class Strength

Age structure is a basic characteristic of a population that represents the proportions of fish belonging to each age group. As a population increases or declines, the number of fish in each age group fluctuates and the age structure, a function of recruitment and mortality, will vary accordingly (OMNR 1983). A shift in age structure towards younger fish is often associated with increasing levels of exploitation and a shift towards older fish may signal recruitment problems (OMNR 1983). The age structure of a population can also be altered by exceptionally strong or weak year-classes as they move through the various age groups (Colby 1984). Variations in year-class strength may also serve as indicators of stress (OMNR 1983).

To manage for a sustainable lake whitefish fishery in Lake Nipigon, Ritchie (1989) recommended the age structure of the commercial catch be composed of a minimum of three age groups that contribute more than 15 percent (each), and two or more of the three age groups should be 75 percent mature (which corresponds to lake whitefish greater than seven years of age in Lake Nipigon).

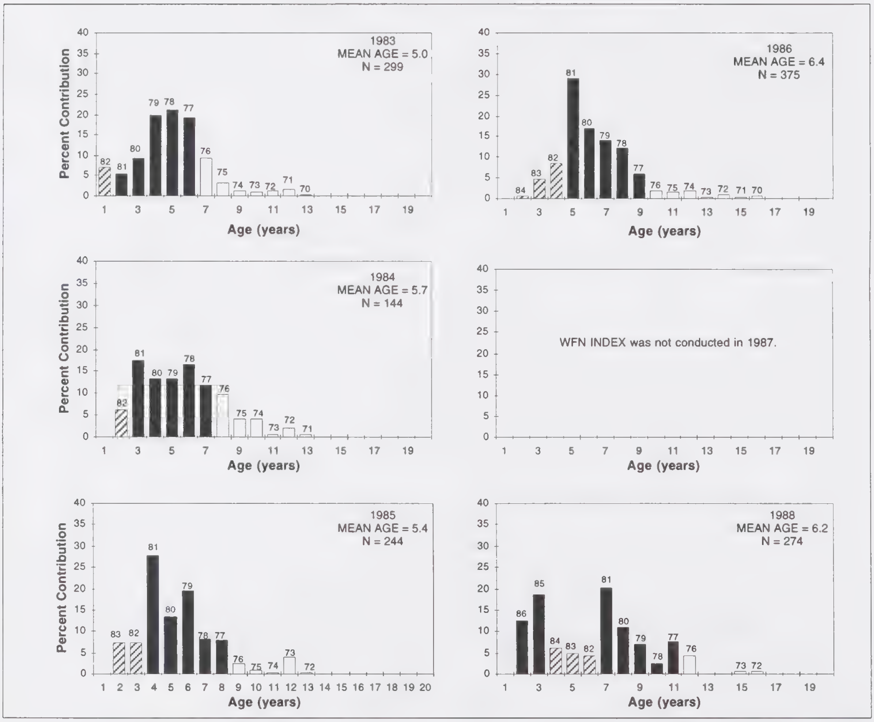


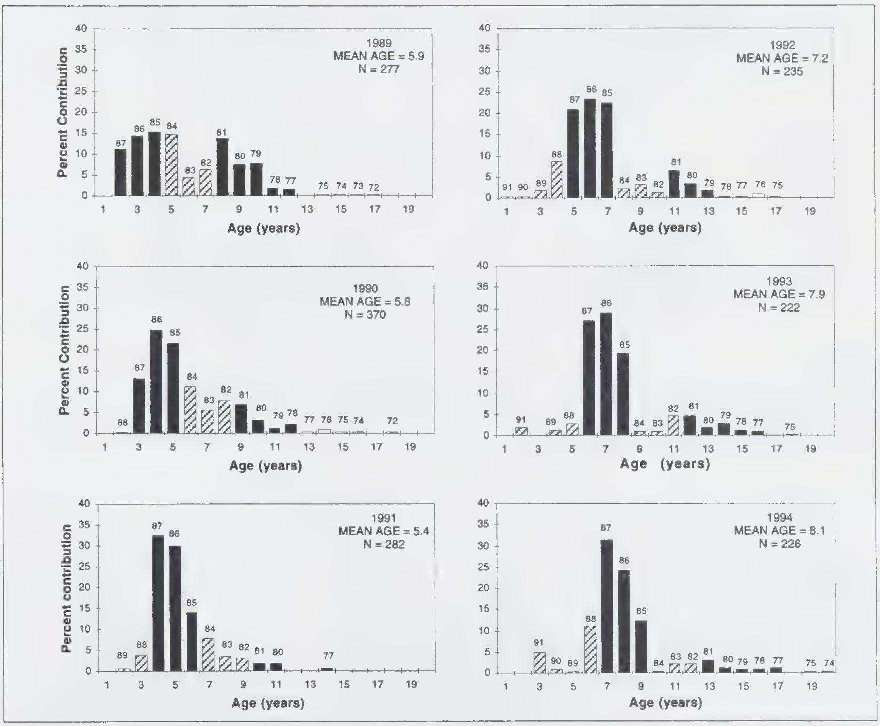
Figure 7:
Lake whitefish age composition—WFN (1983–1994). The percent contribution of each age group and corresponding year-class to annual index catches is represented by the height of each histogram bar. Year-class strength is indicated by bar shading: weak year-classes are hatched and moderate to strong year classes are solid (black). The sample year, mean age of the catch, and sample size are presented in the top right corner.

Age composition histograms for annual index fishing programs are presented in Figures 7 and 8. A comparison of relative year-class strength is presented in Figure 9.

LNFAU index fishing provides consistent samples of lake whitefish from three to 12 years of age. Lake whitefish are fully recruited to Index gear at age five or six. Index catches are composed of 10 to 22 age groups with fish from one to 28 years of age. The effects of strong and weak year-classes on age structure can be observed as they move through the various age groups represented in annual index catches over the 1983 to 1994 sampling period (Figures 7 and 8).

A shift in Age Structure towards an older age composition and reduced recruitment of younger age groups is evident in index catches from both sampling locations.

Large fluctuations in year-class strength of six to eight fold are evident in index catches of lake whitefish (Figure 9). Successively strong year-classes were produced during 1977 to 1981 as well as in 1986 and 1987. Below average recruitment of lake whitefish to index catches indicates production of weak year-classes in consecutive years 1982 to 1984 and again in 1988.



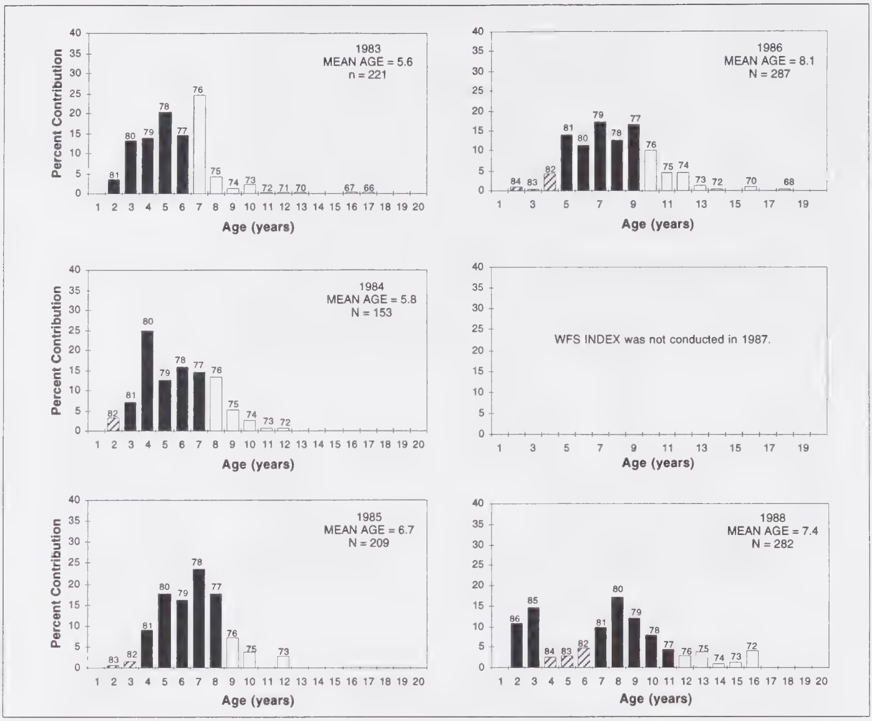
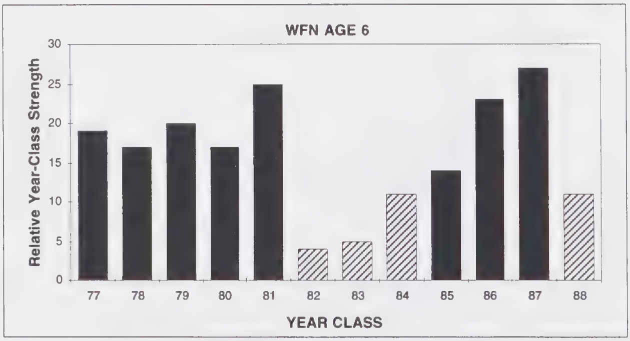
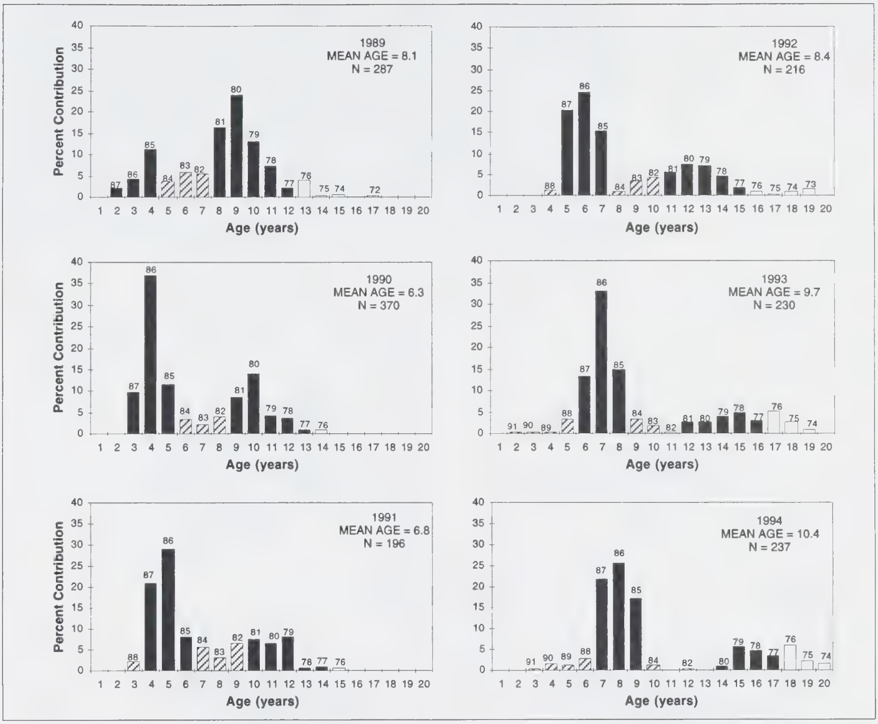


Figure 8:
Lake whitefish age composition—WFS index (1983–1994). The percent contribution of each age group and corresponding year-class to annual index catches is represented by the height of each histogram bar. Year-class strength is indicated by bar shading: weak year-classes are hatched and moderate to strong year classes are solid (black). The sample year, mean age of the catch, and sample size are presented in the top right corner.





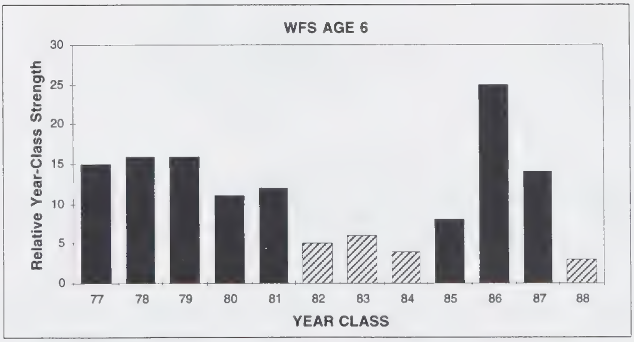


Figure 9:
Lake whitefish year-class strength. The percent contribution of age six fish to index catches (1983–of relative year-class strength. Solid (black) bars indicate moderate to strong year-classes and hatched bars indicate weak year-classes.

Commercial catches of lake whitefish are composed of nine to 18 age groups with fish from three to 20 years of age being harvested (Figure 10). Lake whitefish are fully vulnerable to commercial gillnets by age eight. A shift in age structure towards an older age composition and reduced recruitment of younger age groups is also apparent in the commercial fishery.

The relatively strong 1977 to 1981 year-classes all contribute more than 15 percent to the commercial catch in three or more consecutive years ,and two of these age groups were 75 percent mature (older than age seven). However, this criteria has not been met since 1990. The 1982 year-class only contributed more than 15 percent to the commercial catch on one occasion, as eight year-old fish in 1990. The weak 1983 and 1984 year-classes have not contributed 15 percent to the commercial catch in any year (Figure 10).

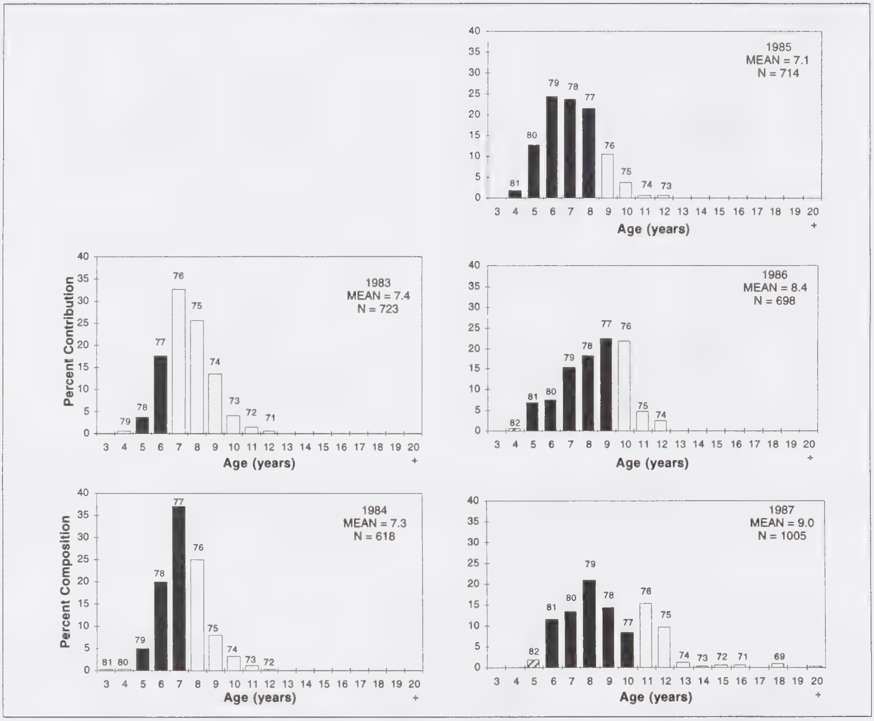
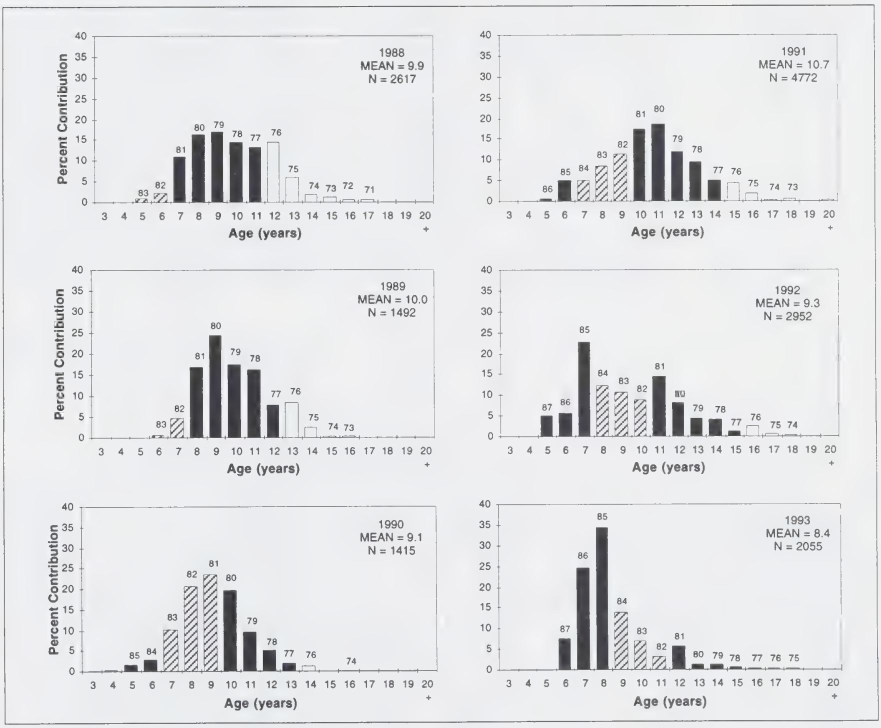


Figure 10:
Age composition of commercial lake whitefish catches (1983–1993). The percent contribution of each age group and corresponding year-class to commercial catches is represented by the height of each histogram bar. Year-class strength is indicated by bar shading: weak year-classes are hatched and moderate to strong year-classes are solid (black). The sample year, mean age of the catch, and sample size are presented in the upper right corner of each histogram.



1988
MEAN = 9.9
N = 2617
1991
MEAN = 10.7
N = 4772
1989
MEAN = 10.0
N = 1492
1992
MEAN = 9.3
N = 2952
1990
MEAN = 9.1
N = 1415
1993
MEAN = 8.4
N = 2055
Percent Contribution
Age (years)

Mean Age

Mean age of the catch is a statistic that describes the average length of time that fish remain in a population (OMNR 1983). Exploitation stress is often indicated by a declining trend in mean age. Conversely, an increasing trend may signal recruitment failure (OMNR 1983, Colby 1984).

Although the mean age of lake whitefish catches has not exhibited large fluctuations over the sampling period (WFN: CV=0.16 ,WFS: CV=0.20 , commercial catch: CV=0.14) , an increasing trend is evident over the 1983 to 1994 sampling period (Figure 11).

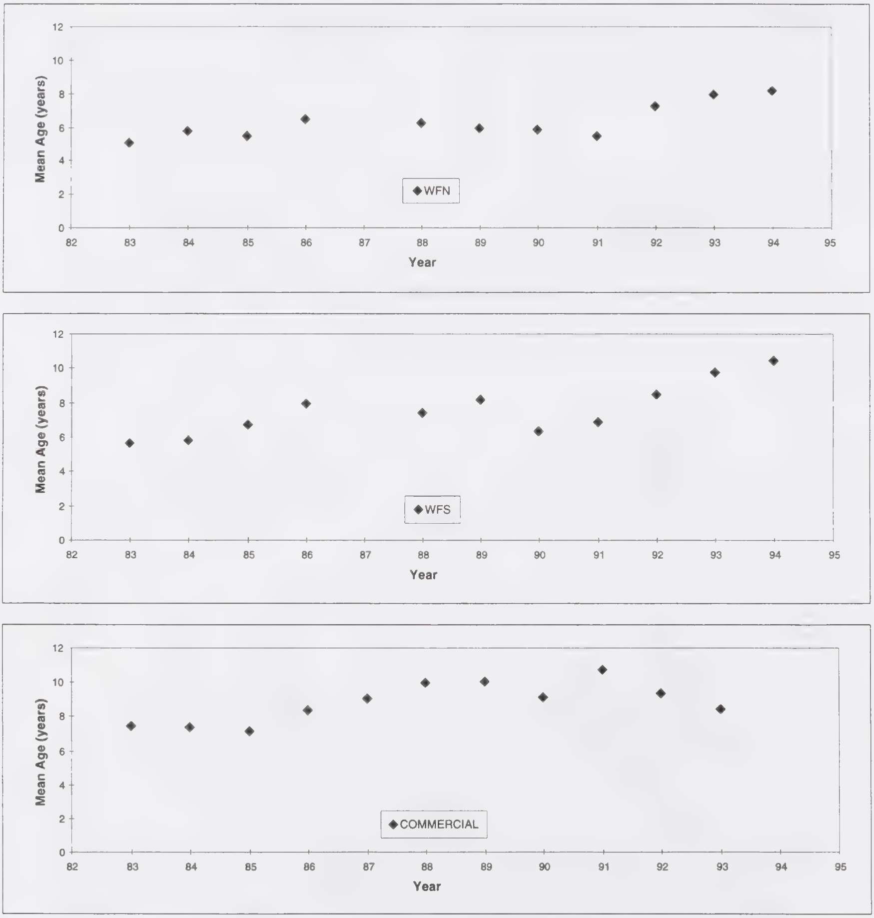


Figure 11:
Trend in mean age of Lake Nipigon whitefish (1983–1994). Mean age values of lake whitefish from WFN and WFS index, and commercial catches are plotted against the corresponding sample year.

Mortality

Total annual mortality is a measure of the decline in numbers of fish in a population due to all causes, including fishing. Annual mortality rates above 60 percent are considered high for lake whitefish populations and may lead to stock instability or collapse (OMNR 1983).

Total annual mortality rates were estimated using cumulative catch curve analysis—a modification of the standard catch curve method (Ricker 1975; Van Den Avyle 1993) that reduces the influence of varying year-class strength and small sample size on mortality estimates (Korver 1995). Due to gear selectivity, mortality estimates from index gillnet catches tend to be under-estimates and commercial gillnet catches are likely to produce over-estimates of mortality (OMNR 1983).

LNFAU index catches and commercial catches provide estimates of total annual mortality that average 40 and 49 percent, respectively, over the sampling period (Table 3).

Table 3:
Lake whitefish total annual mortality (TAM) rates derived from index and commercial catches (1983-1994).

	Index Catches (ages: 6–12)		Commercial Catches (ages: 8–12)
Sample Year	WFN TAM (%)	WFS TAM (%)	TAM (%)
1983	37	48	68
1984	42	50	69
1985	34	46	67
1986	43	37	59
1987	index not conducted		36
1988	34	40	34
1989	41	43	43
1990	40	31	50
1991	42	25	34
1992	36	27	36
1993	38	45	46
1994	49	58	na
	Mean = 40 SD = 4	Mean = 41 SD = 10	Mean = 49 SD = 14

Spawning Opportunities

The number of spawning opportunities afforded to an "average fish" can be estimated by the Abrosov Index ("t-values") which compares the mean age of the catch to the mean age at maturity (OMNR 1983). Abrosov (1969) suggested that the average number of spawning opportunities (t-values) should exceed 1.5 to maintain stable populations of commercially harvested fish species. However, where environmental conditions remain favourable, a mean age at or near the age of maturity may be adequate to sustain lake whitefish populations as positive t-values imply stability and are generally viewed as safe (OMNR 1983).

The Lake Nipigon commercial fishery usually provides more than one spawning opportunity to lake whitefish and t-values generally approach or exceed the recommended value of 1.5 (Table 4).

Table 4:
The number of spawning opportunities provided by the commercial lake whitefish fishery.

Year	Mean Age of Catch (years)	Mean Age at Maturity (years)		# of Spawning Opportunities (Abrosov "t-values")	
		WFN	WFS	WFN	WFS
1983	7.4	4.2	6.9	3.2	0.5
1984	7.3	5.2	7.0	2.1	0.3
1985	7.1	6.3	7.0	0.8	0.1
1986	8.4	6.1	7.2	2.3	1.2
1987	9.0				
1988	9.9	6.0	7.2	3.9	2.7
1989	10.0	6.1	7.5	3.9	2.5
1990	9.1	6.9	7.3	2.2	1.8
1991	10.7	7.4	7.9	3.3	2.8
1992	9.3	7.5	7.4	1.8	1.9
1993	8.4	8.5	8.7	-0.1	-0.3
1983–1993	8.8	6.4	7.4	2.4	1.4

Interactions between Rainbow Smelt and Lake Whitefish

The invasion of rainbow smelt into freshwater lakes has had a major influence on the structure of fish communities and yields of individual species (Colby *et al.* 1987) with recruitment failure of lake whitefish reported as the most common response (Evans and Loftus 1987). Case studies provide evidence that predation by adult smelt on young lake whitefish and competition between their young are the probable cause of recruitment failure (Loftus and Hulsman 1986; Evans and Loftus 1987; Evans and Waring 1987).

Rainbow smelt abundance, although highly variable (CV=0.78), has exhibited an increasing trend over the 1982 to 1994 sampling period. It is assumed that smelt abundance was low prior to 1982 as their presence in Lake Nipigon was only first reported in 1976. Following two or three years of population increase (1982-1984), the smelt population declined rapidly to the lowest recorded levels of abundance (1985-87), then quickly rebounded and increased to high levels of abundance (1988-1994).

Prior to 1982, the variability in lake whitefish recruitment (1977-1981 year-classes) was low (WFN: CV=0.17 , WFS: CV=0.16). Since that time, a large variation (WFN: CV=0.63 , WFS: CV=0.84) in recruitment of lake whitefish has become evident (Figure 12).

Lake whitefish year-class strength declined during the initial period of smelt abundance (1982-1984) and subsequently increased following the rapid decline in smelt abundance (1985-1987). Lake whitefish recruitment declined again in 1988 as the smelt population was increasing in abundance (Figure 12).

Lake whitefish recruitment has become more variable and appears to be inversely related to rainbow smelt abundance.

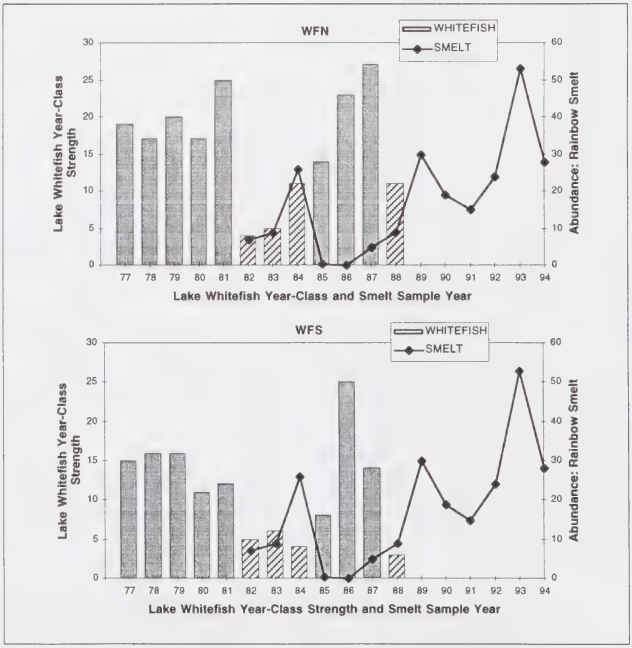


Figure 12: Relationship between rainbow smelt abundance and lake whitefish year-class strength. The median index fishing catch-per-unit-effort (CUE) of rainbow smelt is the measure of smelt abundance and is represented by the solid line. The relative strength of 1977–1988 lake whitefish year-classes is illustrated by shaded bars: solid bars indicate moderate to strong year-classes and hatched bars indicate weak year-classes. the percent contribution of age six lake whitefish to index catches is the measure of year-class strength.

Note: The strength of the 1989–1994 year-classes has not been measured as these fish are not yet fully vulnerable to the index fishing gear.

Appraisal of the Lake Whitefish Fishery

The biological indicators examined provide the following evidence:

- Lake whitefish are being utilized at full potential yield.
- Variation in annual abundance is approaching critical levels.
- Age specific growth rates are stable.
- An increasing trend in age at maturity is evident and may signal a response to stress.
- The age structure is getting older and there has been a decline in recruitment of younger fish which is reason for concern.
- Year-class strength has become more variable and the presence of consecutively weak year-classes indicate recruitment problems.
- An increasing trend in mean age is indicated and may signal recruitment failure.
- Total annual mortality of adult lake whitefish does not appear to be excessively high.
- The commercial fishery usually provides more than one spawning opportunity to lake whitefish.
- Increasing abundance of rainbow smelt appears to be having a negative effect on lake whitefish recruitment.

Conclusions

- The Lake Nipigon whitefish population is exhibiting signs of recruitment failure—a negative interaction with rainbow smelt is the likely cause.
- Given the increasing trend in smelt abundance, impaired recruitment of lake whitefish is expected to be very evident in the 1989 to 1994 year-classes.
- Lake whitefish are being harvested at maximum levels and yields are likely to decline as successively weak year-classes enter the fishery.
- If concerns over recruitment failure materialize as anticipated, allocation and harvest levels of lake whitefish should be reduced to compensate for a declining spawning stock.

Management Recommendations

- To manage for a sustainable fishery, the total allowable harvest of lake whitefish should be maintained below potential yield (258 540 kg/yr)
- Reductions in allocation and harvest will be necessary to ensure conservation of lake whitefish stocks if recruitment failure materializes as expected.
- Managers are also encouraged to maintain healthy populations of lake trout, brook trout, walleye, northern pike and other predator species as a means of limiting rainbow smelt abundance and protecting a balanced fish community.

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